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SMALLPOX SURVEILLANCE IN THE STRATEGY OF GLOBAL ERADICATION

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Smallpox surveillance represents the single most important component of the present global eradication effort. In fact, the ultimate success or failure of the eradication programme depends principally upon our capability to develop an effective surveillance system in each country and on a global basis. It is only within the past three years, however, that this has been fully appreciated.

In the past, a programme of smallpox eradication was considered to be synonymous with a mass vaccination campaign. Originally, national programmes were so designed. Some were effective but many were not. When it became apparent that mass vaccination alone was often unsuccessful, programmes were enjoined to increase their targets for vaccination coverage from 80% to 100%[1]. The actual objective of the programme, "the eradication of smallpox" was obscured by an alternative goal, "vaccination of 100% of the population".

While total vaccination of the entire population is a worthy objective and, if successful, would assure eradication of smallpox, such coverage is logistically and practically impossible. In fact, as efforts are made to increase vaccination coverage beyond 80% to 85%, the costs and difficulties increase logarithmically while immunity levels increase arithmetically. Even with 90% of the population vaccinated, smallpox transmission may still persist. On the other hand, it is known that some countries have become smallpox-free at a time when much less than 80% of their populations have been vaccinated. It is thus more logical to consider the strategy of smallpox eradication in terms of the actual objective, "eradication of smallpox", and to determine how best to interrupt transmission of the disease rather than to pursue blindly a simple programme of mass vaccination.

The most direct approach to eradication is to interrupt transmission of smallpox through the containment of outbreaks. We know that focal outbreaks of smallpox can be rapidly and effectively controlled. Even in countries such as Ceylon or the United Kingdom, for example, where immunity levels are actually poorer than in most presently endemic countries, outbreaks have been rapidly terminated by comparatively limited but specific containment measures. The explanation is simple. When a country becomes smallpox-free, the occurrence of a single suspect case is usually cause for alarm and the problem is dealt with as a public health emergency. Containment of the outbreak, especially at an early stage, is really not difficult. In endemic countries, however, health authorities and indeed the population as a whole frequently have come to regard the disease as an inevitable occurrence; the various sites which could report cases often do not do so or they report only after a long delay. This is not surprising for, until surveillance-containment programmes have been developed, there is little motivation to report cases. Rarely is help provided to deal with outbreaks and thus there is no reason to report. By the time the problem is recognized, the outbreak has spread throughout one or more health jurisdictions and sometimes to other areas. Of course, if the population has a high level of immunity, transmission will proceed more slowly and an outbreak, even though detected only after many weeks, may be reasonably readily contained. If there is a very low level of immunity, however, the disease may spread more rapidly and containment procedures are less likely to be successful.

As we consider the strategy of the global eradication programme, it is useful to keep these points in mind and to recognize, first, that the objective of the programme is to interrupt the transmission of smallpox; second, that the most direct way to interrupt the transmission is to detect and contain outbreaks of the disease; and, third, that the systematic programmes of vaccination, while unquestionably important, are basically to facilitate the execution of surveillance-containment operations.

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Least developed, and in some countries, virtually non-existent at the beginning of the global eradication programme was the most important component - surveillance. It is well to recall that the surveillance of smallpox is probably easier than for any other communicable disease. In smallpox, the infected person develops a distinctive rash which is wholly characteristic in the great majority of cases[2]; the rash is most dense over the face and hands, the unclothed readily visible portions of the body; persons with subclinical infections are rare and are of little importance since they do not appear to be able to transmit the disease to others[3]. In brief, the disease characteristics are such that there is little difficulty in detecting visually whether or not the virus is present in an area. The rash is sufficiently characteristic in the great majority of cases that laboratory confirmation is academic. In addition, in the instance of variola major, fully 75 per cent of cases are left with visible scars[4], most notable over the face. This permits us to appraise the extent of past infection by simple surveys which determine the prevalence of the characteristic facial scars. By relating these observations to the age of the individual, we can also ascertain the most recent period when infection was present. If, for example, a country believes itself to have been free of smallpox for 5 years and characteristic facial scars are observed in a 2 year old child, a detailed investigation would be warranted to determine by history whether or not the scars could have been caused by smallpox and, if so, where the infection occurred.

The first requisite in surveillance, identification of where the disease exists, is thus comparatively simple.

Additionally, smallpox has several epidemiological characteristics which, as a group, are unique. In brief, these are as follows:

1. Smallpox is transmitted solely from man to man. There are no known animal reservoirs; [2,5] insects appear to play no role.

2. Detection and recognition of the disease is a comparatively simple matter, as previously noted. Persons with subclinical infection are rare and of little importance epidemiologically since they do not appear to be able to transmit disease.

3. The infected individual is capable of transmitting infection during a comparatively brief period - from emergence of the first lesions until the scabs have fallen off - a period of about four weeks. Following infection, he has essentially permanent, lifetime immunity.

4. Transmission requires close contact between infected and susceptible individuals and most commonly occurs in the home, the hospital or school.

5. Epidemics develop comparatively slowly. Between each generation of cases, there is a period of two to three weeks. In most circumstances, the infected individual transmits disease to not more than 2 to 5 other persons.

It is precisely these characteristics which permit the surveillance activities in a smallpox eradication programme to be as highly effective and practicable as they are. The significance of these characteristics is better appreciated as one considers the manner in which the transmission of smallpox is sustained.

Since smallpox is transmitted solely from man to man and since the infected individual can only transmit the disease over a period of four weeks or less, it is apparent that a "chain of infection" is required if the disease is to remain endemic in an area. For smallpox to persist, an infected person with clinically apparent disease must infect a second person who similarly must develop clinically apparent

illness and so on to subsequent generations. Since there is a lapse of two to three weeks between generations of cases, we can by simple arithmetic determine that the most tenuous chain of transmission in a country requires that at least 15 to 25 cases occur annually. If fewer cases than this are recorded, only two explanations are possible: reporting is incomplete, or the cases represent reintroductions of smallpox. It is also apparent that when any country reaches the level of perhaps 200 to 500 cases in a year, there are few chains of infection extant and that fairly simple containment procedures should readily and rapidly be able to interrupt transmission.

Transmission most commonly occurs as a result of close contact as in a household, hospital or school. Contrary to common belief, casual contact as might occur in markets or on public transportation comparatively infrequently results in transmission. Noted below are four illustrative outbreaks.

Locale of infection	Locale of Infection of Cases in Five Outbreaks				
	United Kingdom 1961-1962	Sweden 1963[7]	Kuwait 1967[8]	Abakaliki Nigeria 1967[9]	Bawku Ghana 1967[10]
Imported	5	1	1	1	?2
Household (or compound)	17	13	1	30	58
Hospital and other medical	39	13	32	0	0
Market	0	0	0	1	3
Other & unexplained	6	0	8	0	5
	67	27	42	32	68

Despite the fact that in each of these outbreaks, there were a number of patients who were ambulatory following the onset of illness and in casual contact with many persons, comparatively few cases occurred which could not be readily traced to household or hospital contact. Often disregarded in the tracing of cases, the hospital can be an important source as illustrated in the first three outbreaks. Although in outbreaks cited above, contact in schools played no apparent role, studies in Brazil have shown that the schools may also be instrumental in some circumstances in disseminating infection throughout a community[11]. Since hospitals are few in number in endemic countries, it is evident that most individuals must acquire infection through household contact as, in fact, they do. Since the infected persons rarely transmits disease to more than 2 to 5 additional persons, the disease spreads comparatively slowly, usually among other household residents, neighbours and visiting relatives. Not unexpectedly, then, smallpox occurrence is characterized by highly localized focal outbreaks involving a comparatively few houses or a few villages in an area. This is quite the reverse of the common belief that when smallpox occurs in a country, it is a widely dispersed infection with single cases scattered over an extensive geographic area.

In this context, it is interesting to note recent observations in India and Pakistan, two countries which account for two-thirds or more of all recorded cases of smallpox. In Pakistan, during the course of one year, an intensive surveillance programme was conducted in a rural district of 1.2 million persons.[4]

During the period, 1,040 cases occurred, an incidence as high as that observed anywhere in the world. However, throughout the course of the entire year, only 170 of the 1,700 villages (10%) were infected with smallpox. In December 1967, an assessment survey in a highly endemic district of India,[12] similarly revealed that during the course of the year only 101 of 2,331 towns and villages were afflicted with smallpox.

At no time were more than 20 (1%) of the villages afflicted and, at the seasonal low point of smallpox, only seven villages recorded disease. Thus, even in these highly endemic areas, smallpox occurred not as a widely dispersed sporadic transmission. Prompt case investigation coupled with active efforts to trace infection sources and comparatively simple containment activities could have had a major impact on disease incidence and might well have terminated all transmission. One effective epidemiological team in each of these Districts could have dealt with the problem.

Vaccination programmes conducted during past years undoubtedly have had a decided influence in reducing the proportion of susceptibles and thus reducing the probability of further spread. Successful vaccination confers substantial protection for many years and undoubtedly is partially protective for at least 10 to 20 years. Although the duration of protection conferred by a single successful vaccination is unknown, recent data show almost universally that 85% to 95% or more of all cases have no scar of vaccination to confirm the fact that they had been successfully vaccinated. The impact of prior vaccination is most vividly illustrated by studies conducted by Rao and his colleagues in Madras.[13] They found that among 103 unvaccinated family contacts, 37% contracted the disease while among 1,108 who had at some time been vaccinated, only 1% contracted smallpox.

Frequency of smallpox among vaccinated and unvaccinated contacts - Madras[13]

Age	No. of unvaccinated* contacts	No of cases of smallpox	No of previously vaccinated contacts	No of cases of smallpox
0-4	57	23	118	0
5-14	18	4	287	2
15-44	15	9	543	10
45+	13	2	160	1
	103	38 (37%)	1,108	13 (1%)

*Unvaccinated at time of exposure.

Further, those previously vaccinated who did contract smallpox were far less effective in transmitting it than were those individuals who were unvaccinated.

Frequency of transmission from unvaccinated and previously vaccinated cases to vaccinated and unvaccinated contacts, Madras, India[13]

	Contacts					
	Vaccinated			Unvaccinated		
	No.	No. developing smallpox	%	No.	No. developing smallpox	%
Case - previously vaccinated	527	2	0.4	32	9	28
Case - unvaccinated	619	12	1.9	71	29	41

This observation is consistent with laboratory studies which have shown that the quantity of virus excreted by a patient correlates with the number of lesions present in the mouth.[14] Individuals who have previously been vaccinated tend to have fewer lesions both on the skin and on the mucous membranes and so excrete less virus and have greater difficulty in infecting others. Those with significantly attenuated illnesses and few lesions, the group which may be troublesome diagnostically are fortunately of less epidemiological significance for this reason.

As the unvaccinated play the major role in perpetuating smallpox transmission, the strategy of eradication campaigns has focused particularly on identification of which groups are especially poorly vaccinated. The word "group" is stressed for it is obvious that unvaccinated individuals widely scattered throughout a well vaccinated community do not encounter sufficient susceptibles to sustain the chain of transmission of smallpox for very long and the disease soon dies out. A group of major concern in most countries are those in the lower socio-economic stratum in the cities and towns. Significant numbers in the lower socio-economic groups are poorly vaccinated migrants, often from rural areas, who enter the cities and settle among other migrants in densely crowded quarters. Smallpox is readily transmitted under such circumstances. As the migrants travel back to the rural areas, either permanently or to visit, they carry the disease with them. Vaccination programmes in urban areas have rarely in the past made provision for intensive and repeated vaccination campaigns in this highly mobile, rapidly changing group.

A second principal group of concern is children. In most countries, two-thirds or more of all cases occur among those less than 15 years of age. Several studies have shown that young children in particular are excellent vectors of the disease. As children tend to move more actively throughout a community than do their elders, they transmit infection more widely and often serve to transmit the disease between houses or compounds.

But, in countries with limited health facilities, how can a surveillance programme be expected to function? Repeatedly, we are told that medical personnel are nil, that there is no one who can report cases of smallpox and that there are great uncharted sparsely populated areas in which there are few or no government facilities at all. If we keep in mind certain of the characteristics of smallpox epidemiology which we have discussed and bear in mind that there must be a chain of transmission for the disease to sustain itself, the problem, as most of you know, is much less impossible than would first appear. In the least developed countries, one consistently finds a surprising number of widely distributed government and mission hospitals, aide posts and the like which regularly attend to persons who are ill. In several endemic countries, malaria workers visit all houses over vary large areas every 30 days. The first step, therefore in the surveillance operation is to identify those who can report suspect cases, to enlist their support and to promote regular and prompt reporting from each as to whether or not smallpox cases have been observed. Since in endemic areas, even the local populace is frequently astute in smallpox diagnosis, this simple network may be augmented by soliciting reports of suspect cases from schoolteachers, village development workers, village headmen, etc. At the same time, the reporting network is being set up, mobile investigation and outbreak containment teams are created. In highly endemic areas, one team may be required to cope with problems in a population area as small as perhaps 1 to 2 million persons. As incidence falls, one team may be sufficient for an areas encompassing 5 to 25 million persons. Such teams, by simply carrying out their responsibilities, demonstrate to all concerned that there is a reason to report cases - that action is taken on the basis of the reports received. Obviously all cases will not initially come to recognition. Outbreaks may occur in remote villages and be undetected. But, keeping in mind that for smallpox to persist as an endemic disease, an uninterrupted chain of infection is necessary, it is apparent that outbreaks in remote areas will either die out or come to recognition when the sources of infection of subsequent cases are sought. As noted previously, smallpox does not erupt as a sudden conflagration involving thousands of cases but, rather, outbreaks evolve comparatively slowly with intervals of two to three weeks between generations of cases and with comparatively few becoming infected from each successive case. Thuse, although four, five or six generations of cases are missed, an outbreak even at that point in time is numbered not in thousands but, at most, by a few hundreds of cases or less and is manageable by isolation, rapid widespread vaccination and tracing of infection sources.

Interruption in the chains of transmission of smallpox can occur very rapidly. The most notable example in the current eradication effort is that of your own countries in west and central Africa. When it is considered that the programme began less than three years ago and in some countries less than two years ago; when it is recalled that the population is 120 million persons distributed over an area larger than India or Brazil, with health services and medical resources substantially less than either country; when it is realized that immunization levels at the beginning of this programme were but a fraction of those presently observed in Asian countries, the reduction in smallpox incidence to virtually nil levels in this brief period is an amazing achievment. I am confident that your surveillance programme accounts, in major part, for this success.

Does this mean that every last person or every last village has been vaccinated? We know that they have not! But systematic vaccination has served to reduce transmission to the point where surveillance measures have been able to interrupt the chain of infection. Surveillance has been the specific, the definitive weapon in this campaign.

That surveillance is the key to the eradication programme is clear. Let me go one step further and say that if the responsible authorities in all endemic countries were to comprehend fully the importance of this measure and were to take definitive action along the lines noted, global smallpox eradication within a period of three years could be a practical reality.

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